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Specialists in A/V solutions, strategic planning, and architectural acoustics.

July, 13th 2010

City of Ankeny
210 S Ankeny Blvd
Ankeny, IA 50023

Attn: Mr. Todd Redenius - Director of Parks & Recreation

Re: Wagner Park Band Shell – Noise Measurements

Dear Mr. Redenius,

Please find the enclosed information regarding our findings regarding noise level measurements which were taken by our staff on the afternoon of July 12th 2010. The area of concentration was the green space north of the band shell site in Wagner Park and the adjoining Hawkeye Park area bordering residential neighborhoods to its north.

In short, the measurements taken onsite support our initial suspicions that the proximity of the north bordering neighborhood is in direct conflict with amplified sound type events being held in at the band shell location. Furthermore, our findings indicate that the band shell structure itself has little impact on the surrounding neighborhoods to the north, but is however beneficial as a barrier to sound propagation for neighborhoods to the south.

The enclosed information within the following report is technical in nature. We have attempted to simplify the concepts and information presented as to allow lay persons to gain the most benefit from the information contained as much as possible.

If you have any questions or concerns regarding the information contained within, please do not hesitate to contact me and I will be happy to discuss in detail any such questions.

Sincerely,
Audio Engineering Group

Todd Berger CET – Senior Systems Engineer

Ankeny Wagner Park Band Shell / Hawkeye Park Onsite Sound Measurements

The following information was collected between the hours of 1:00pm and 4:30pm on July 12th 2010 at the Wagner Band shell facility located at 410 West 1st Street in Ankeny, IA. Data collection was performed by Todd Berger CET – Senior Systems Engineer of Audio Engineering Group, with assistance by Tim Koskamp – Systems Engineering Support also of Audio Engineering Group.

General Site Conditions

At the time of measurement collection thunderstorms were in the vicinity with passing showers and light drizzle throughout the time period used for collect. Weather conditions as reported at the Ankeny Regional Airport indicated the following conditions;

Winds	350 degrees at 6knots / 060 at 6knots
Temperature	19 Degrees C (66.2 F)
Dewpoint	18 Degrees C (64.4 F)
Barometer.	29.82 In Hg

Test Measurement Equipment Used

Test equipment was utilized in conjunction with the parks and recreation department's sound reinforcement system as a sound source. The test rig consisted of a time energy frequency analyzer, calibrated measurement microphone with wireless link, microphone calibrator, and laptop PC with software as follows;

Goldline TEF25	Time Energy Frequency Analyzer
Goldline TEF04	Measurement Microphone
Galaxy CMC200A	Microphone Calibrator
Lectrosonics TM400	Wireless Measurement Microphone Link
Soundlabs Software	Core Build 6.7.9

The TEF, measurement microphone, and wireless microphone link was calibrated on site using the CM200A calibrator to a sound pressure level of 94dB at 1kHz prior to the start of measurements and periodically throughout the measurement session.

Types of Measurement Acquired

Sound Pressure Levels (Weightings Flat / A / C)

Exponential Slow Response with 3.1 second with 1/6 octave resolution

ETC (Energy Time Curve)

2.0 second sweep between 200Hz to 2000kHz with a collection time span of 1.723 seconds comprised of 8192 samples

TDS (Time Domain Spectrometry) (Flat response)

5.547 second sweep form 100Hz to 16kHZ across 1024 samples. Time window bandwidth of 53.4Hz and receive delay set to the appropriate ETC time for the measurement position.

Frequency Response

The audible frequency range in human hearing is 20Hz to 20,000Hz (20kHz). Frequency is often referred to as pitch where sounds lower in pitch are lower in the frequency spectrum and those sound higher in pitch are higher in frequency.

Humans have a hearing curve that allows us to be more responsive to receiving higher frequencies than lower frequencies. This is referred to as the "equal loudness curve" and thus our hearing is much more sensitive at higher frequencies than lower ones.

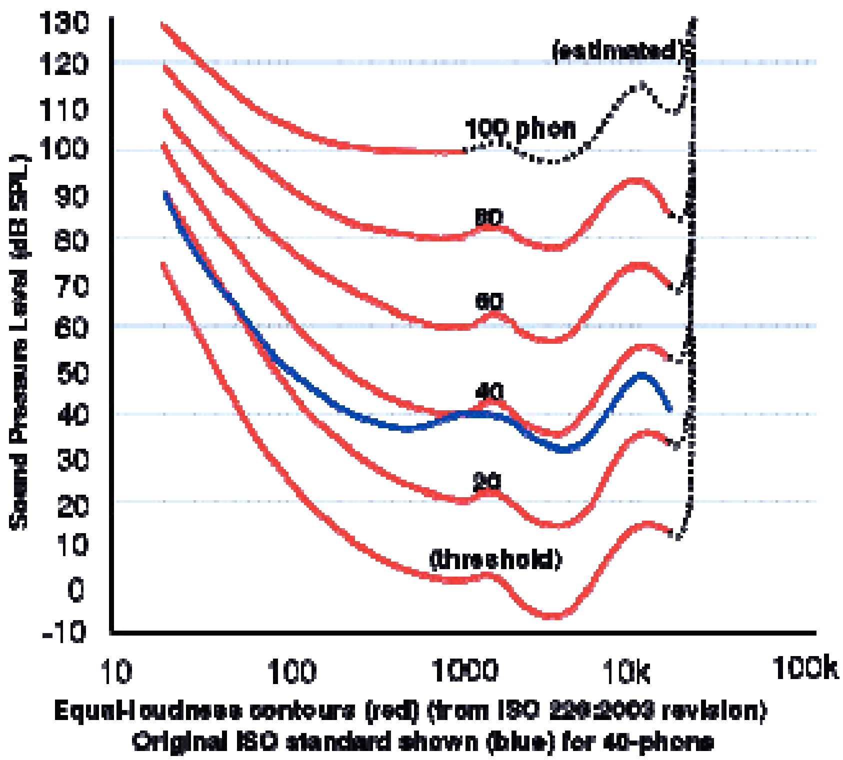


Figure 1

Figure 1 shows an equal loudness curve illustrating how humans perceive sound levels at various frequencies. As an example, as sound must be approximately 80 dB SPL at 1000Hz where a 20 Hz tone must be 100dB SPL to be perceived as the same level.

The Decibel Scale

For the purpose of this report we will refer to decibels as a means of measuring loudness (sound intensity) of a sound source. The scale is referenced to human hearing with 0 dB (40 phones) being the absolute threshold of human hearing and 120 dB reference being the threshold of pain in most persons. While there is a correlation between acoustic power (L_p) and the decibel it is beyond the scope of this report to explain that correlation in detail Therefore throughout this document we will refer to decibels as a reference to sound pressure levels (i.e Volume Levels).

An important factor to realize about the decibel as it pertains to sound pressure is that the scale is logarithmic, therefore while 3dB + 3 dB equals 6 dB, 3dB + 6 dB only equals approximately = 7.7 dB. Hence a doubling of power shall result in an increase of 3dB in sound pressure level.

Persons perceive the increase decibels in the following manner; (approximations)

+ 10 dB = 2 x the perceived volume
+ 6 dB = 1.5 x the perceived volume
+3 dB = 1.2 x the perceived volume (slightly perceivable by most people)

The decibel when combined with a **weighting scale** is used for sound pressure level measurements depending on the types of data need to be acquired.

SPL Measurement Weightings

Figure 2 shows the weighting system utilized for sound pressure level measurements. For the purpose of this report we will refer to “A” (dBA SPL), “C” (dBC SPL), and “Flat” (dB SPL) for our analysis.

While flat is not indicated on the figure below it considers all sound equal in amplitude regardless of frequency. (i.e. a straight line on the chart below at 0 dB)

dBA SPL is typically used in noise measurement for low level sounds due to the fact it closely resembles the inverse of the curve of human hearing (equal loudness contour – Figure 1) thus is typically used for noise measurement purposes.

SPLC weighting has historically been used as a compromise between dB SPL and dBA SPL as gives more precedence to lower frequencies for noise abatement purposes.

As an excise to better communicate the differences between weighting curves let us consider a single tone noise source at 100Hz at 100 dB SPL. (“Flat”) In an “A weighted” measurement this sound pressure would read approximately 19dB lower or 81 dBA SPL while a “C weighted” measurement it would read only 1 dB lower than a “Flat” measurement or 99 dBC SPL.

Utilizing the same 100 dB SPL signal for a pure tone at 2000Hz the reading would be 102 dBA SPL and 100 dBC SPL.

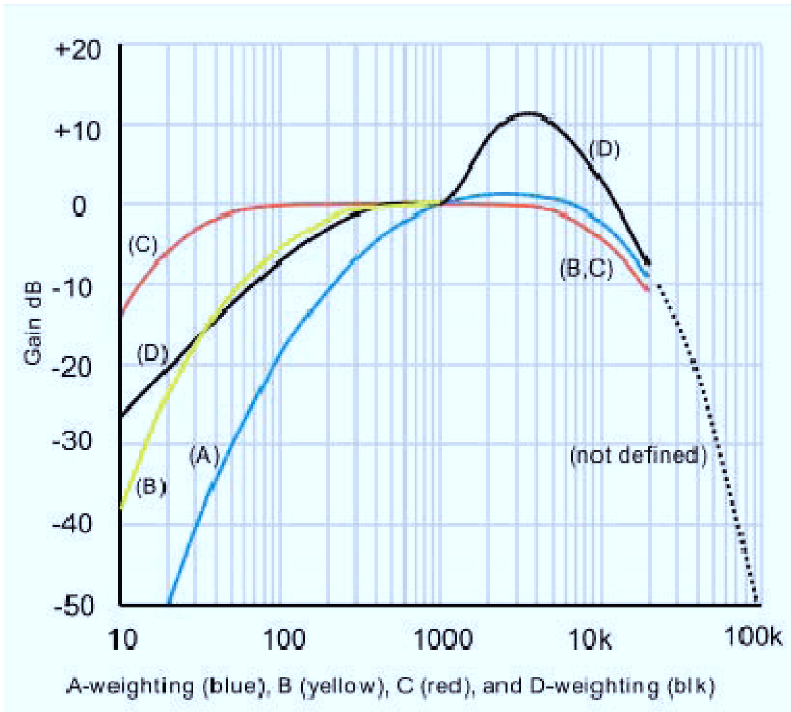
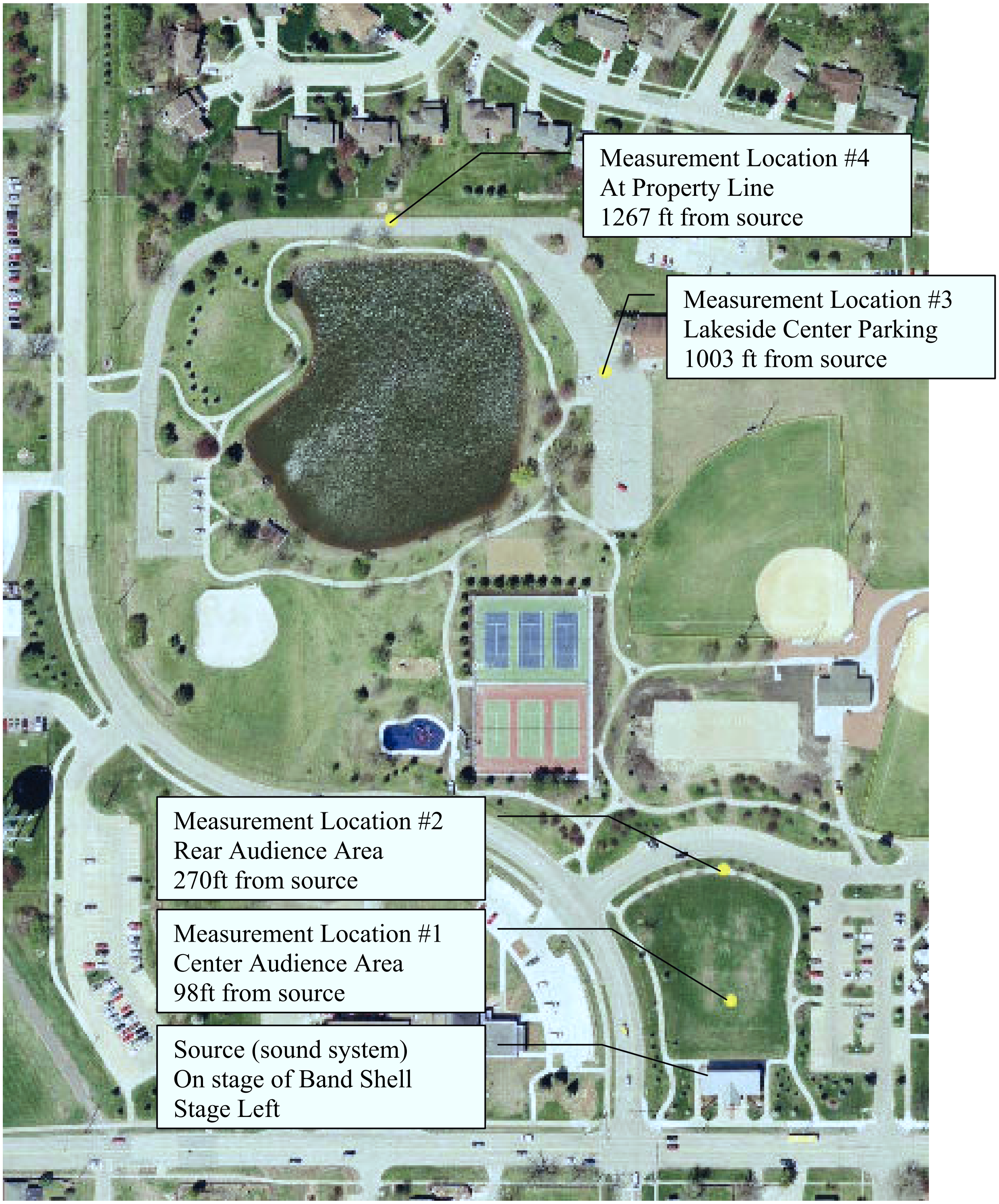


Figure 2



Measurement Location Map

Measurement Locations

Four primary locations were utilized throughout the measurement session as indicated in the map above. These locations shall be herein referred to as measurement locations 1 through 4.

Inverse Distance Law

When sound is unimpeded it will travel at a rate of approximately 1128ft per second in air. (faster in other mediums such as water) As temperatures decrease, the speed of sound will increase slightly with the inverse effect happening as temperature increases.

One can predict the loss of sound pressure level of a free air sound source (a sound source with no surrounding boundaries) based on distance using the inverse distance law which simply states "For every doubling of distance between the sound source and the listener, a decrease in sound pressure of 6dB will occur". However, while this rule is generally true, it is important to realize that higher frequency sounds can be impacted by outside forces more easily than lower frequencies and thus are typically reduced in level faster over great distances.

Measurements Taken

In the instance of the Wagner Park band shell, two predominant factors are in play at most times when the space is functioning for performances. Wind velocity and direction and the degree of foliage present. Wind will affect higher frequencies and can bend low frequency sound waves (diffraction). This variable is a big one in the case of outdoor venues such as the one in question. Sound may be carried for many miles if the SPL is high enough and wind conditions are right. (Simply stated)

The planted foliage around the two parks acts as a noise barrier at higher frequencies and actually absorbs / diffuses much of the acoustical energy (above 600Hz). Therefore, we would expect earlier and later in the year before foliage on trees and plants fully develop, sound shall carry more freely into surrounding areas with little to impede its progress. It is worth noting that these plants have little effect on lower frequency octaves. (bass frequencies).

The table below (Table 1) is comprised of sound pressure level data accumulated during on site measurements at the facility. The various weightings and averaging has been calculated based on actual A weight measurements results.

-	A Weighted SPL		C Weighted SPL		Flat SPL	
Sound Source	104	dBA SPL	106	dBC SPL	107	dB SPL
Location 1	75	dBA SPL	80	dBC SPL	83	dB SPL
Location 2	64	dBA SPL	73	dBC SPL	73	dB SPL
Location 3	50	dBA SPL	67	dBC SPL	67	dB SPL
Location 4	54	dBA SPL	71	dBC SPL	73	dB SPL

Source at Measured at 3.3 feet

Table 1

It is very important to note the difference in location 1 and 4 in terms of dB SPL of varying weighting. The A weighting readings show a loss of 21 dBA SPL, where the C weighting only shows a loss of 9 dBC SPL between the two locations. This is directly attributable to the type of weighting curve used for the measurement and the preferential treatment given to low frequencies by the "A weighted" curve.

As an example a typical amplified music event (rock concert) will have audience (location 1) area levels at 100 to 105 dBA SPL. By extrapolating data based on the measurements taken, you would expect sound levels at location 4 to approach 79 to 80 dBA SPL given the same conditions are present as when our measurements were taken.

<u>Sound Pressure Loss - Distance versus Frequency</u>

A Time Domain Spectrometry measurement was taken at each of four locations to determine the direct loss of sound from the sound source without the effect of surrounding reflections such as building, parking lots, and other surfaces. The goal of this set of measurements was to identify the amount of sound attenuation from the sound source at center octave frequencies to help determine the effects of foliage and the pond adjacent to location #4.

Table #2 shows the resulting difference in measurements taken at each location. Amount of sound pressure loss) It is important to note, due to the fact we exploring the difference between levels at various locations, as the sound source was calibrated differently (higher SPL due to the distances involved) from that of the measurements in Table 1.

Sound Pressure Loss between Locations (dB SPL)

Attenuation Between Locations	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
1 to 4	15.9 dB SPL	22 dB SPL	39.5 dB SPL	28.8 dB SPL	44.4 dB SPL	40.7 dB SPL	61.3 dB SPL
1 to 3	15.7 dB SPL	21.8 dB SPL	23.2 dB SPL	35.9 dB SPL	48 dB SPL	39.4 dB SPL	48.4 dB SPL
1 to 2	8.1 dB SPL	9.9 dB SPL	10.6 dB SPL	10.5 dB SPL	7.9 dB SPL	9.3 dB SPL	7.9 dB SPL

Table 2

The conclusion which can be made from a study of the data presented in Table 2 is that the foliage has a dramatic effect in frequency ranges above 500 Hz in the aid of attenuation while the low frequency energy has much less loss. Note the difference in loss between Locations 1 and 3 versus Locations 1 and 4. The sound attenuation at this low frequency is only .2 dB SPL different even though the distance between locations 3 and 4 increases an additional 265 feet from the sound source.

Also worth noting is the increase in SPL at Location 4 versus Location 3 at 1000Hz and 2000Hz. Even though location 3 is closer to the sound source than location 4, the latter location had less sound pressure loss due to the effect of the open pond and the lack of foliage present between Location 4 and the sound source.

The Effect of Ambient Noise

For a person with "normal" hearing to decipher clear sounds, that sound must be approximately 15 dB SPL to 20 dB SPL above the noise floor for the sound information to be useful and clearly defined. Many outside noise sources can contribute to the ambient noise floor present. In the case of an outdoor venue such as Wagner Park, traffic, occupants of the adjoining recreational areas, wind, and audience levels will all play an important role in the ambient noise levels at the facility.

During our measurement session we recorded an "A weighted" ambient noise measurement at both Location 1 and Location 4 for a reference as follows;

- Location 4 = 40 dBA SPL
- Location 1 = 55 dBA SPL

Based on the information above, it is obvious that in order for events to be heard clearly at location 1, it will be necessary to provide levels in access of 70 to 75 dBA SPL throughout the audience areas adjacent to the band shell for events However, this assumes that noise sources are below 55 dBA SPL. In the case of Wagner Park, we find it very likely that noise floor will increase from local traffic requiring a higher minimum level based on time of day and traffic volume. (Reference: unamplified human speech is 70 to 75 dBA dBA SPL dependant on the talker)

Reflection Paths

Sound will reflect off hard surfaces (such as the ceiling structure of the band shell) and be redirected at the same angle of incidence as the sound wave striking such surface. The angle, size, and mass of the object will determine at what frequencies the "reflector" will redirect sound. When dealing with smaller objects, only higher frequencies will reflect off a surface. When dealing with large surfaces both high and low frequencies reflection will occur. (Frequency of the reflector is directly proportional to the surfaces size).

In the case of the band shell at Wagner Park, we took several ETC (energy time curve) measurements to look for reflection paths specifically from the band shell structure. While several are present inside the immediate audience area, (at Locations 1 and 2) we could identify no paths from the band shell which were contributing to sound levels at Locations 3 and 4. The design of the band shell is such that the majority of the reflected energy is being directed into the audience are directly in front of the band shell as it should.

Numerous other reflection paths worth noting from the sound source itself did include reflections from the building adjacent to the baseball fields and the Lakeside Center building. These reflections had no impact on location 4 but were apparent at location 1, 2, and 3.

The only sound reflection detectable at location 4 was from the surface of the pond which is apparent at both high and lower frequency bands.

Summary

After completing the site visit and reviewing the measurement data collected, we find that the core issues revolving around this facility regarding noise complaints is simply the close proximity between the band shell area and the measurements location 4. Sound will travel unless it is reflected, diffused, or absorbed.

Fortunately, the foliage present in the parks are impeding sound pressure waves from carrying at higher frequencies. Unfortunately however, there is nothing stopping low frequency energy (which is much more difficult to control) from intruding into the neighborhoods to the north. Add environmental conditions such as wind and temperature as a factor and these sounds may carry for many miles if the sound pressure levels being produced at the band shell are high enough.

For the band shell facility to function as its obvious original intent, an outdoor performance venue, sound levels must be high enough to overcome crowd, nearby traffic, and other ambient noise sources at the audience areas. (a minimum of 15 dBA SPL to 20 dBA SPL above the ambient noise floor for intelligible speech). Simply turning down the volume to a certain level may not be possible if crowd and other ambient noises such as traffic are to be overcome or musical content with soft passages are to be clearly defined.

In an amplified music concert setting, a reasonable level would be expected to approach and could even exceed 100 dBA SPL at measurement location 2. However, these levels will lead to a sound level approaching 80 dBA SPL at measurement location #4 which would most likely be an unacceptable level for neighborhoods bordering this facility.

As we have alluded earlier, low frequency sounds are very difficult to control outdoors as the barrier must be excessively large to help alleviate the transmission of low frequency sounds. Large sound barriers (such as traffic noise barriers) which are also high in Mass could be erected to separate Hawkeye Park from the bordering residential areas, but these barriers would need to be massive structures in excess of 50ft tall to be effective at the lower frequency range which is the primary cause for concern at these distances. Needless to say this would have serious aesthetic implications for this site and will only be marginally effective at very low frequencies below 100 Hz.

Due to the fact little (if any) reflected energy is contributing to levels outside the band shell audience area, acoustically treating the band shell structure itself will do nothing to hinder the low frequency energy at Locations 3 and 4. Furthermore, attempting to treat this facility with sound absorbing materials will most likely make the band shell unusable for unamplified speech and instrumental music. The acoustic shell is the only means of directed amplification for the audience areas in such uses and provides the necessary acoustic blend for instrumentalist.

Many municipalities enact special noise ordinances for such venues based on the type of noise content, functionality requirements, and the hours the facility is in use. The ability of such special noise ordinances to overcome challenges such as the ones you are facing have varying degrees of success. Too often, these ordinances can lead to a hard SPL limit set with no reference to time (noise averaging) nor ambient noise level conditions.

Due to the recurring nature of impulsive sounds from music venues it is doubtful that a complete compromise between the venues functional use (assuming amplified speech and music) and adequate hard noise levels can be legislated based on sound pressure levels alone. This is a complicated set of circumstances which is primarily due to the need to overcome ambient noise at the venue itself, the geographical topology of the area, and proximity of this venue to the residential neighborhood adjoining this facility.

Recommendations/Options

It would be our recommendation to all parties involved that a compromise be developed between the neighborhoods directly affect by the sounds being propagated from the park space with the understanding that a balance must be struck between the functional use of the facility and the amount of disturbance bestowed on the surrounding areas.

In the case of non amplified music, this compromise would primarily reside with the conductor and instrumentalist as little else can be done to control sound except at the source.

In the case of amplified music, electronic monitoring can be integrated (or patched) into a sound reinforcement system to control the overall output of a sound system as a hard limit. Due to the fact the signal is electronic, special digital signal processing equipment along with sensing microphones can compress the audio signal so it may not exceed a predetermined sound level. Many of these systems allow for these levels to be automatically adjusted based on a schedule which includes time of day and week. In researching this technology, we are aware of a technology that is able to compensate for ambient noise levels while ignoring the sound source itself. (Further investigation here would be required in order to confirm published results).

As mentioned earlier, noise barriers may be a partial solution should they be designed and constructed properly as well as placed in the right locations. While these would be physically very large and tall due to the wavelengths of the low frequencies involved, their placement (between the park and neighborhood) could alleviate all but the lowest frequencies should the aesthetic impact of such a structure(s) be tolerable.

Another technology that may assist with properties which directly adjoin this facility would be noise masking technologies. This technology consists of an electronic noise signal being reproduced at a property boundary which mimics a static noise in order to "mask" the offending noise source. Noise masking generally would only be effective only in areas directly adjacent to the Hawkeye Park property line and be very limited in its effective range outdoors. It is important to understand that his technology would require extensive research and engineering on a property by property basis with also very little effectiveness at lower frequencies.

To decrease sound levels in adjacent areas, a sound reinforcement system with narrow dispersion characteristics should be used at the Wagner Park band shell. If the sound source is narrow horizontally, less sound energy would “spill” into adjacent areas. (East and West of the audience area) As with some of the other recommendations here, this will have limited effectiveness at lower frequencies and would most likely require a sound reinforcement system being properly and specifically designed and installed for this facility.

Finally, should you wish to pursue a weighted SPL type of ordinance, it would be our recommendation at this site to include language to base the ordinance on ambient noise levels at the performance site and allow for time of integration compensation for this type of approach to be effective. (Something very few municipalities have done currently or in the past). Enforcement would take likely take specific noise measurement equipment and training to properly document potential violations however.

Closing Observations

The propagation of sound pressure waves from Wagner Park band shell into the residential areas are virtually impossible to completely eliminate due to their close proximity to one another and due to the physical properties of sound transmission. While many of the things outlined within this report may help to relieve some of the annoyances for those residing nearby. Sound will continue to be clearly heard if this facility is to remain an active music venue as currently utilized simply due to proximity and the sound levels required for the audience’s benefit.

Further information regarding the contents of this report should be directed to;

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Attn: Mr. Todd Berger CET